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EXAMINER	
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Please find below and/or attached an Office communication concerning this application or proceeding.

Office Action Summary	Application No. 09/763,009	Applicant(s) BADRI ET AL.
	Examiner Kevin M. Burd	Art Unit 2611

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *01 March 2006*.

2a)☒ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-3 and 6-38* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☒ Claim(s) *2-4,7-10 and 38* is/are allowed.

6)☒ Claim(s) *1,11,12,20-23,25,27 and 30* is/are rejected.

7)☒ Claim(s) *13-19,24,26,28,29 and 31-37* is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other: _____.

1. This office action, in response to the remarks filed 3/1/2006, is a final office action.

Response to Arguments

2. Applicant's arguments filed 3/1/2006 have been fully considered but they are not persuasive. Applicant challenges the effective data of the Segal reference. Copies of the provisional applications to which the Segal reference claims priority are provided. Support is found in 60/083,934, figures 3-5 and 7 and pages 2 and 3. Support is found in 60/083,952, figure 4. For these reasons and the reasons stated in the previous office action, the rejections of the claims are maintained.

Claim Rejections - 35 USC § 102

The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (e) the invention was described in (1) an application for patent, published under section 122(b), by another filed in the United States before the invention by the applicant for patent or (2) a patent granted on an application for patent by another filed in the United States before the invention by the applicant for patent, except that an international application filed under the treaty defined in section 351(a) shall have the effects for purposes of this subsection of an application filed in the United States only if the international application designated the United States and was published under Article 21(2) of such treaty in the English language.

3. Claims 1, 11, 12, 20-23, 25, 27 and 30 are rejected under 35 U.S.C. 102(e) as being anticipated by Segal et al (US 6,647,069).

Regarding claims 1 and 20, Segal discloses a method and transmitter for transmitting information symbols using a plurality of carriers (column 8, lines 37-60).

Figures 10 and 11 show data bits being transmitted on separate carriers and at separate times (column 8, lines 53-60). The symbols are different from one another as shown in figures 12A and 12B. Each of the constellation points are on a signal constellation diagram having a predefined number of different states and the symbols comprise different states as shown in figures 12A and 12B. In 16QAM constellations, each point will have different amplitude and phase states with respect to the other points.

Regarding claims 11 and 30, Segal discloses a method and transmitter for transmitting information symbols using a plurality of carriers (column 8, lines 37-60). Figures 10 and 11 show data bits being transmitted on separate carriers and at separate times (column 8, lines 53-60). The symbols are different from one another as shown in figures 12A and 12B. Each of the constellation points are on a signal constellation diagram having a predefined number of different states and the symbols comprise different states as shown in figures 12A and 12B. In 16QAM constellations, each point will have different amplitude and phase states with respect to the other points. The receiver shown in figure 4 will receive these transmitted symbols, demodulate the symbols and recover the original information symbols (figure 4).

Regarding claims 12 and 21, the carriers are different from one another (column 8, lines 44-46).

Regarding claim 22, data is grouped into information symbols. Figure 11 shows 16QAM is used for transmission. Figure 14 shows an example of the mapping scheme comprising 4 bits per symbol.

Regarding claim 23, figure 10 shows a plurality of paths utilizing a plurality of channels. Each of these channels will utilize its own modulation scheme.

Regarding claim 25, each of the transmitted symbols has a point in the constellation and each point in the constellation is assigned a phase value.

Regarding claim 27, Receiver 411 comprises a matched filter, which performs a convolution of a square-root raised cosine filter (column 5, 45-50). This convolution will also take place in the transmitter, in the square-root raised-cosine filter 408.

Allowable Subject Matter

4. Claims 2-4, 7-10 and 38 are allowed.

5. Claims 13-19, 24, 26, 28, 29 and 31-37 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Conclusion

THIS ACTION IS MADE FINAL. Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any

extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of this final action.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Kevin M. Burd whose telephone number is (571) 272-3008. The examiner can normally be reached on Monday - Friday 9 am - 5 pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Jay Patel can be reached on (571) 272-2988. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

Kevin M. Burd
4/28/2006

Kevin M Burd

KEVIN BURD
PRIMARY EXAMINER

Method and Apparatus for Robust Communications over Noisy Communications Systems

Field of the invention

The present invention relates to communication methods and systems in conjunction with digital communications systems.

Summary of the Invention

The present invention seeks to provide method and apparatus for robust communications over noisy communications channels by means of data re-transmission and/or diversity techniques. The present invention can be implemented in full compliance with current network specifications and/or on top of the existing specifications in a manner that enables co-existence of advanced modems designed according to the present invention with current modems.

List of Figures

Figure 1 depicts a CATV digital communications system operative according to the Data Over Cable (DOCSIS) MCNS specification [1].

Figure 2 depicts a frequency grid over the upstream channel of a CATV network operative according to the MCNS specification.

Figure 3 depicts a general scheme utilizing diversity and/or re-transmission techniques over different MCNS channels.

Figure 4 depicts a signal re-transmission technique that can be used in conjunction with the specific embodiment.

Figure 5 depicts symbol mapping that can be used in conjunction with the re-transmission technique depicted in Figure 4.

Figure 6 depicts a signal diversity technique that can be used in conjunction with the specific embodiment.

Figure 7 depicts symbol mapping that can be used in conjunction with the diversity technique depicted in Figure 6.

Description of a Preferred Embodiment

The preferred embodiment is a multi-user digital communications network that operates over cable television (CATV) infrastructure. It is an upgrade of a network that operates according to the MCNS communications specification [1] for transmitting data over CATV.

Basically the target is to increase channel throughput and robustness without complicating the unit at the subscriber side. The are two kinds of services over CATV, and for each service there is a different performance target:

a) Data services (e.g., Internet Access): For these services one would want to maximize packet throughput. In that context we should consider packet error rate. Low delay is not essential in this application.

b) Multi-media services (speech, video, etc., and particularly telephony over cable): For these services one would want to minimize the periods of a high Bit error Rate (BER) (e.g. BER>1e-4). Low delay is essential in this application.

From engineering point of view, it is essential to have a simple and robust apparatus that is suitable for a wide range of channel impairments. These channel impairments may include ingress noise, burst noise, impulse noise, linear distortions, non-linear distortions, and adjacent channel interference.

Figure 1 depicts a CATV digital communications system operative according to the MCNS specification [1]. The system consists of cable modems (CMs) 101a, 101b, CATV transmission medium 102, and a cable modem terminating system (CMTS) 103, which is part of the CATV head-end equipment 104. The information is transmitted through the downstream channel 105 from the CMTS to the CMs, and through the upstream channel 106 from the CMs to the CMTS.

The CMs 101a 101b contain upstream transmitters 107a 107b which receive input data 108a 108b and transmit it using QPSK/16QAM modulation scheme with a configurable transmission pulse, pre-equalizer parameters, power level, carrier frequency, symbol clock, and Reed-Solomon forward error correction code parameters. The transmission is done in a burst mode FDMA/TDMA (frequency/time division multiplexing access) where each CM transmits requests for bandwidth allocation, and where the channel allocator 109 sends to the CM control messages via the downstream channel, indicating the time period in which the addressed CM can transmit. The CM is capable of modifying its signal parameters including transmission power, carrier frequency, transmission pulse, and pre-equalizer parameters, according to control messages from the channel allocator 109.

The CMTS contains a receiver 110 and a channel allocator 109. The receiver 110 detects the information bits fed into the inputs 108a 108b of the upstream transmitters 107a 107b. It estimates the parameters of the received signals, and transfers them to the channel allocator 109. The channel allocator 109 then allocates frequency ranges and configures transmission parameters for the individual CMs in a manner that will make efficient use of the channel bandwidth and will enable the receiver to detect the signals properly.

Figure 2 depicts a frequency constellation of a CATV network operative according to the MCNS specification. Signals 201a-201c have the same nominal symbol rate, while signal 201d has a larger symbol rate, and signal 201e has a lower symbol rate. The nominal bandwidth of each signal 201a-201c is 1.25 times the respective symbol rate.

Re-transmission techniques and/or diversity techniques are useful when the receiver is in-capable of detecting the transmitted data from a single transmission. There are different MCNS channels, e.g.:

a) Different time slots

b) Different carrier frequencies

A general scheme that utilizes diversity and/or re-transmission techniques over different MCNS channels is illustrated in Figure 3. A 1:N rate encoder 301 is operative to reproduce the current symbol or the current FEC block N times. Each reproduced symbol/block is transmitted using N MCNS signals 302 to be communicated to the CMTS over N different channels 303. It is recognized that the N channels represent physical (e.g.,

different carriers) and/or logical channels, and may overlapped in frequency. The outputs 304 of the N channels are fed to a receiver 305 which performs weighted soft combining of the received signals 304. The soft combining comprises Mean Squared Error (MSE) estimation as well as identification of burst noise within the packet, followed by weighted (or selective) combining, accordingly. The receiver may also incorporate joint equalization of the received signals.

The system in Figure 3 can also be interpreted as a re-transmission technique, in which the first MCNS signal transmitted over the first channel is the original message, while all subsequent messages are requested by the CMTS one at a time (or several at a time) to be re-transmitted. A soft combining method applied to all the received messages is also possible.

For example, only if a Reed-Solomon block is received wrongly, a request for re-transmission (possibly at a different carrier) is sent from the CMTS to the CM via the downstream channel

We note that if a Reed-Solomon block is received wrongly, then instead of asking for re-transmission, the CMTS tells the CM what it received, so that the CM can send to the CMTS a short correction message (rather than sending the whole packet again). For example, the CMTS may send back to the CM an indication of the quality level of the detected symbols or the detected symbols themselves. Since the downstream channel is much wider and more reliable than the upstream channel, this approach may be feasible.

In the particular retransmission scheme depicted in Figure 4, a different mapping for 16QAM is used for the re-transmission. Two symbols mapping are given in Figure 5, where A1, A2, A3, A4, B1, B2, B3, B4, C1, C2, C3, C4, and D1, D2, D3, D4 represent the 16 combinations of 4 bits.

Figure 6 depicts a signal diversity system. Two information bits, [b1(n) b2(n)] 601 per symbol are transmitted. The symbols are 16QAM and they are mapped via the signal mapping 602 as a function of [b1(n) b2(n) b1(n-*D*) b2(n-*D*)], where *D* is a delay 603. The mapping scheme is shown in Figure 7.

The result is that bursts of length *D* symbols may be recovered. In this approach, there may be a change in carrier frequency between two transmissions of the same data, which can be used to protect from narrow band interference.

References

[1] Data-Over-Cable Interface Specifications: Radio Frequency Interface Specification SP-RF1101-970321, MCNS Holdings, L.P., March 21, 1997

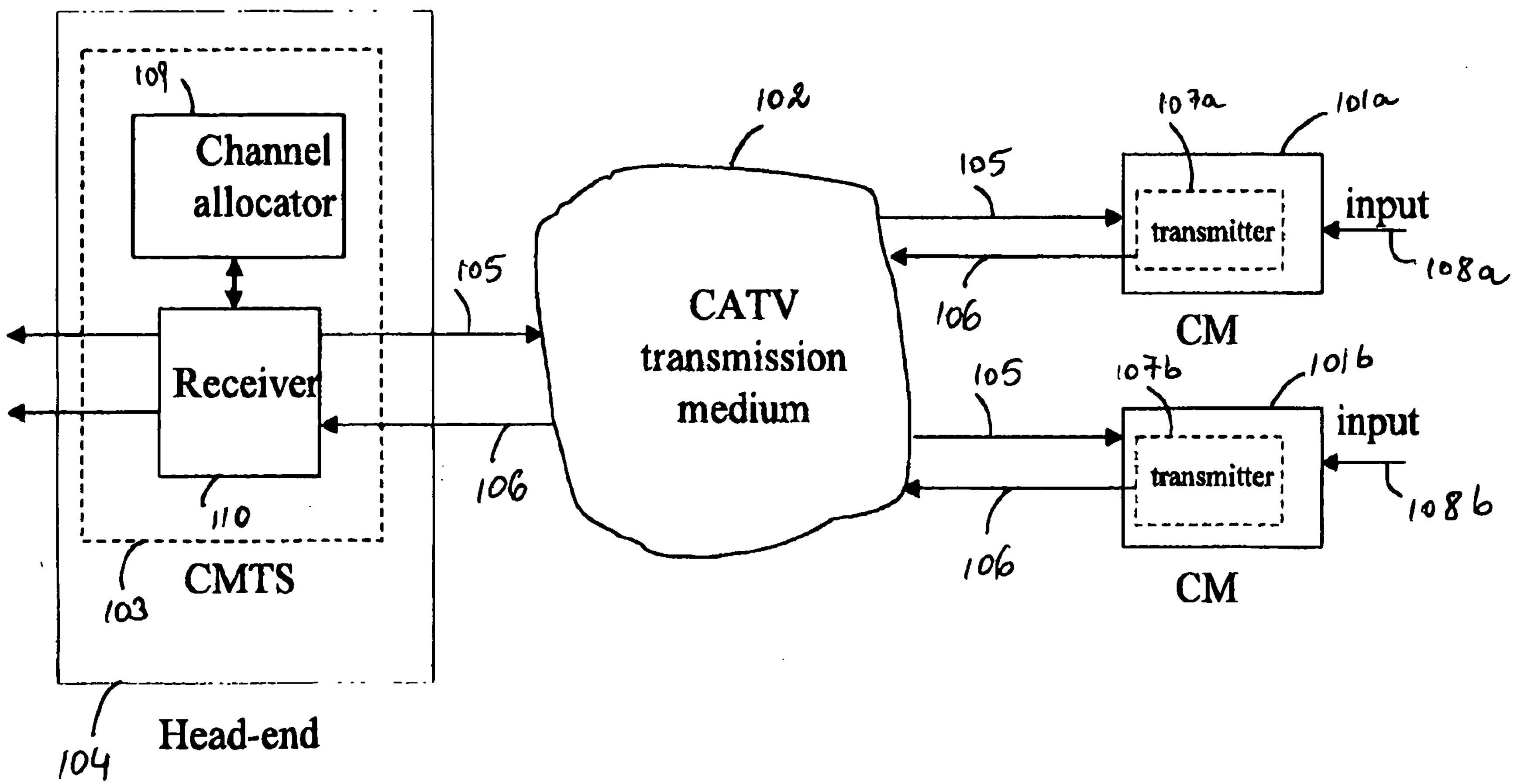


Figure 1

LIBIT Confidential

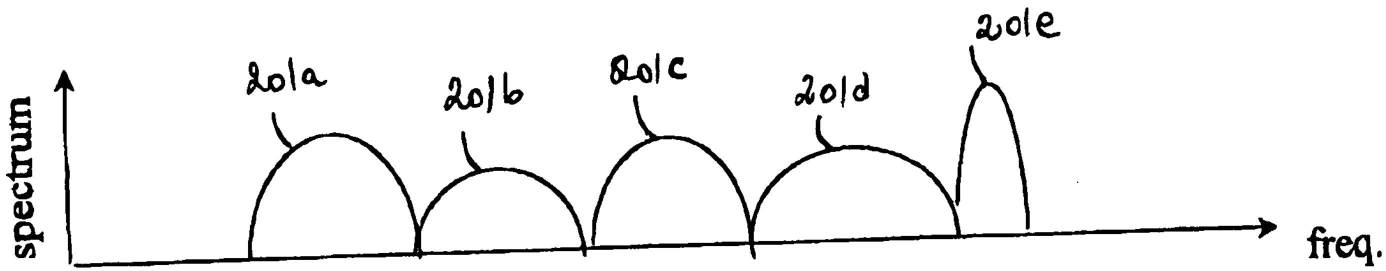


Figure 2

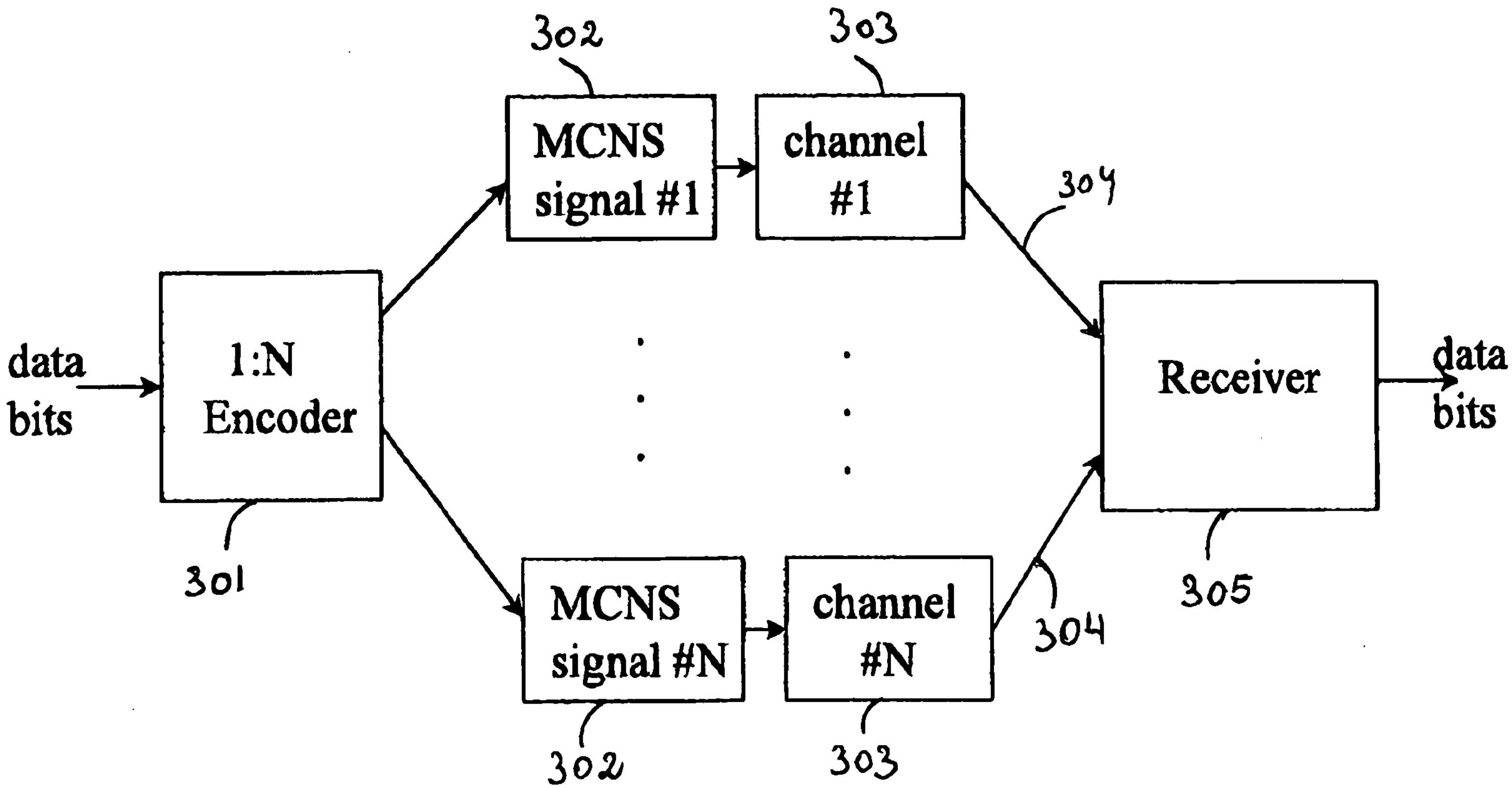

data
bits
1:N
Encoder
301
302
MCNS
signal #1
303
channel
#1
304
MCNS
signal #N
302
channel
#N
303
304
Receiver
305
data
bits

Figure 3

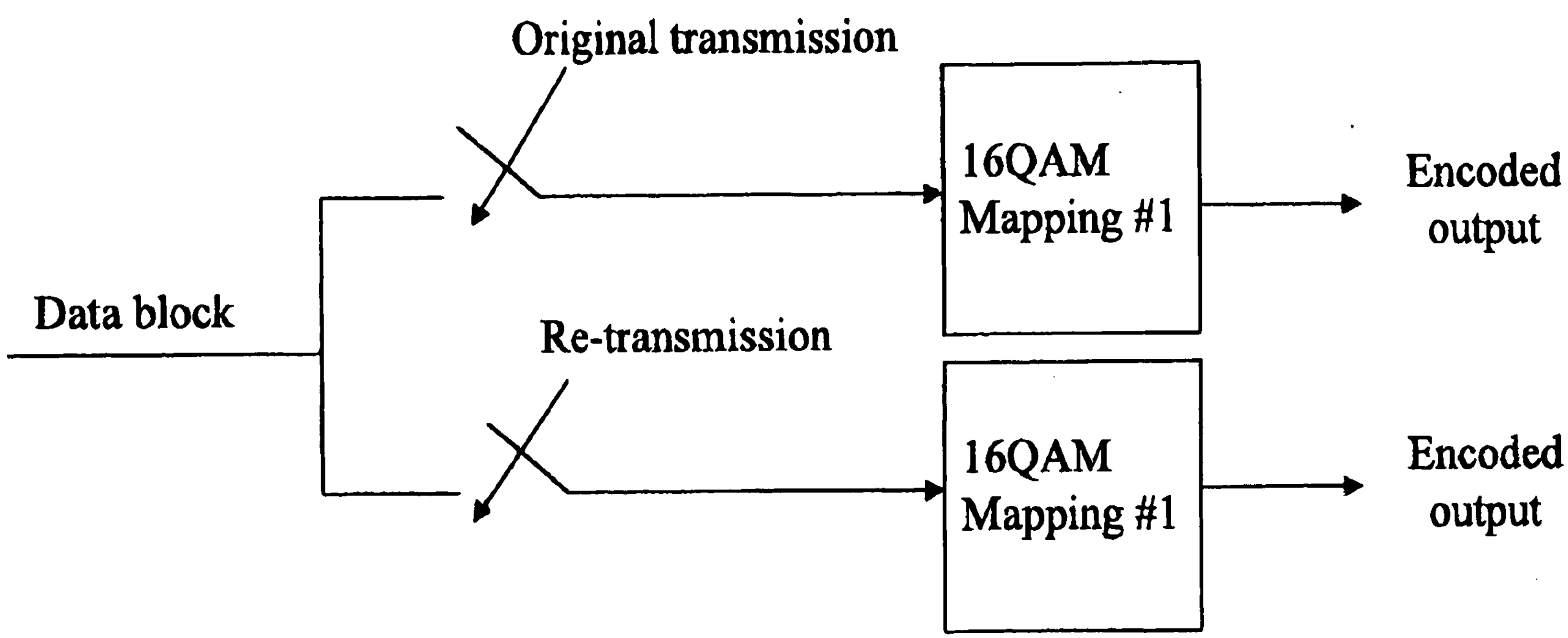

Original transmission
Data block
Re-transmission
16QAM
Mapping #1
16QAM
Mapping #1
Encoded
output
Encoded
output

Figure 4

Mapping 1

1st symbol

A1	A2	A3	A4
B1	B2	B3	B4
C1	C2	C3	C4
D1	D2	D3	D4

2nd symbol

C3	C1	C4	C2
A3	A1	A4	A2
D3	D1	D4	D2
B3	B1	B4	B2

Mapping 2

1st symbol

A1	A2	A3	A4
B1	B2	B3	B4
C1	C2	C3	C4
D1	D2	D3	D4

2nd symbol

C2	C4	C1	C3
A3	A1	A4	A2
D2	D4	D1	D3
B3	B1	B4	B2

Figure 5

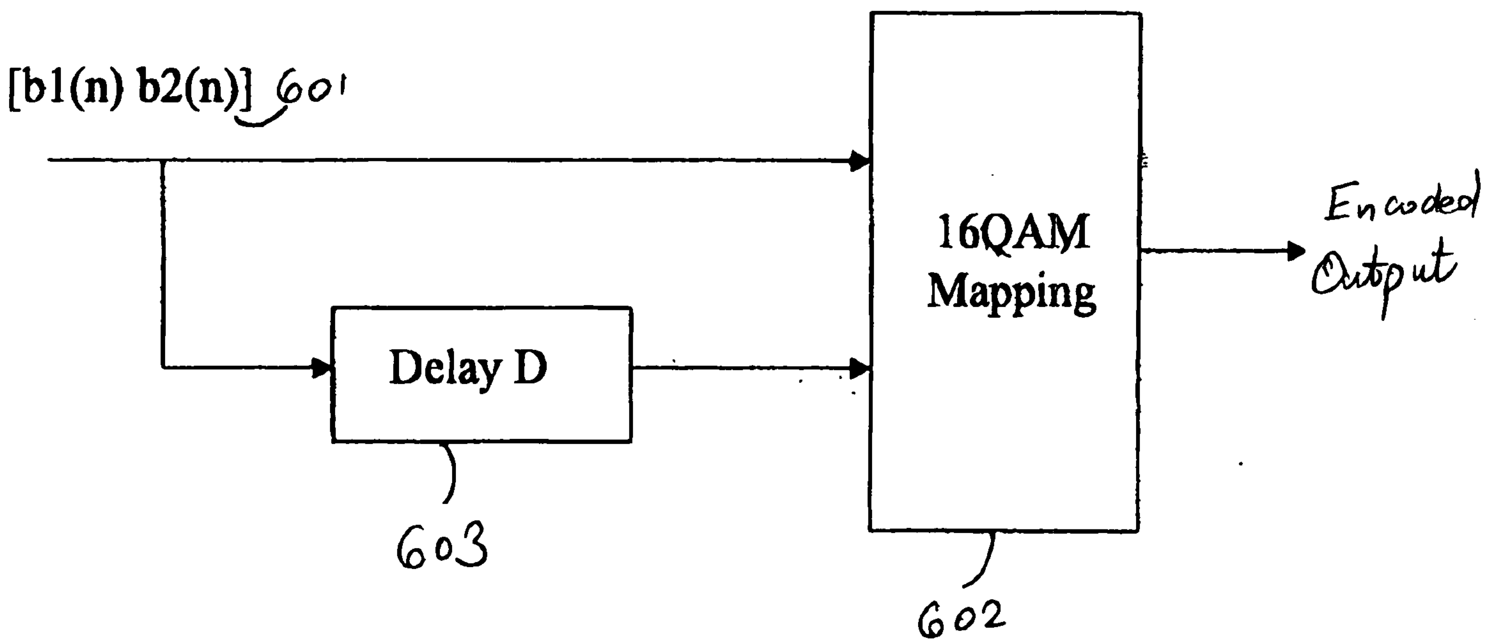


Figure 6

0000	0001	0100	0101
0011	0010	0111	0110
1100	1101	1000	1001
1111	1110	1011	1010

Figure 7

Method and Apparatus for Capacity Increase and Enhanced Communications Performance in CATV Networks

Field of the Invention

The present invention relates to communication methods and systems in conjunction with CATV systems.

Summary of the Invention

The present invention seeks to provide method and apparatus for increasing channel throughput and communications robustness in the return channel of CATV networks. The present invention can be implemented in full compliance with current CATV network specifications and/or on top of the existing specifications in a manner that enables co-existence of advanced modems designed according to the present invention with current modems.

List of Figures

Figure 1 depicts a CATV digital communications system operative according to the Data Over Cable Interface Specification (DOCSIS) by the MCNS Holdings, L.P.CNS [1].

Figure 2 depicts a frequency grid over the upstream channel of a CATV network operative according to the MCNS specification.

Figure 3 depicts a reduced channel spacing frequency grid of the upstream channel that can be used in conjunction with the MCNS specification according to the present invention.

Figure 4 depicts a simplified block diagram of a communications apparatus constructed and operative for upstream CATV applications according to the present invention.

Figure 5 depicts an example of an adaptive equalizer that can be used in conjunction with the preferred embodiment.

Figure 6 depicts a structure of a decoder that can be used in conjunction with the preferred embodiment.

Figure 7 depicts a structure of a modified Reed-Solomon decoder that can be used in conjunction with the preferred embodiment.

Description of a Preferred Embodiment

The preferred embodiment is a multi-user digital communications network that operates over cable television (CATV) infrastructure. It is an upgrade of a network that operates according to the MCNS communications specification [1] for transmitting data over CATV.

Basically the target is to increase channel throughput and robustness without complicating the unit at the subscriber side. The are two kinds of services over CATV, and for each service there is a different performance target:

a) Data services (e.g., Internet Access): For these services one would want to maximize packet throughput. In that context we should consider packet error rate. Low delay is not essential in this application.

b) Multi-media services (speech, video, etc., and particularly telephony over cable): For these services one would want to minimize the periods of a high Bit error Rate (BER) (e.g. BER>1e-4). Low delay is essential in this application.

From engineering point of view, it is essential to have a simple and robust apparatus that is suitable for a wide range of channel impairments. These channel impairments may include ingress noise, burst noise, impulse noise, linear distortions, non-linear distortions, and adjacent channel interference.

Figure 1 depicts a CATV digital communications system operative according to the MCNS specification [1]. The system consists of cable modems (CMs) 101a, 101b, CATV transmission medium 102, and a cable modem terminating system (CMTS) 103, which is part of the CATV head-end equipment 104. The information is transmitted through the downstream channel 105 from the CMTS to the CMs, and through the upstream channel 106 from the CMs to the CMTS.

The CMs 101a 101b contain upstream transmitters 107a 107b which receive input data 108a 108b and transmit it using QPSK/16QAM modulation scheme with a configurable transmission pulse, pre-equalizer parameters, power level, carrier frequency, symbol clock, and Reed-Solomon forward error correction code parameters. The transmission is done in a burst mode FDMA/TDMA (frequency/time division multiplexing access) where each CM transmits requests for bandwidth allocation, and where the channel allocator 109 sends to the CM control messages via the downstream channel, indicating the time period in which the addressed CM can transmit. The CM is capable of modifying its signal parameters including transmission power, carrier frequency, transmission pulse, and pre-equalizer parameters, according to control messages from the channel allocator 109.

The CMTS contains a receiver 110 and a channel allocator 109. The receiver 110 detects the information bits fed into the inputs 108a 108b of the upstream transmitters 107a 107b. It estimates the parameters of the received signals, and transfers them to the channel allocator 109. The channel allocator 109 then allocates frequency ranges and configures transmission parameters for the individual CMs in a manner that will make efficient use of the channel bandwidth and will enable the receiver to detect the signals properly.

Figure 2 depicts a frequency constellation of a CATV network operative according to the MCNS specification. Signals 201a-201c have the same nominal symbol rate, while signal 201d has a larger symbol rate, and signal 201e has a lower symbol rate. The nominal bandwidth of each signal 201a-201c is 1.25 times the respective symbol rate.

An example of a reduced channel spacing frequency grid with which the present invention can be used is depicted in Figure 3. The channel spacing is less than the signal bandwidth, which is 1.25 times the symbol rate of the signals. It is recognized that such system uses overlapped transmission scheme and therefore falls under the category of the US patent 5,710,797 Jan. 20, 1998 assigned to Libit Signal Processing Ltd. incorporated herein by reference [2].

Reference is now made to Figure 4 which is a simplified block diagram of a communications apparatus constructed and operative for upstream CATV applications according to the present invention. The apparatus of Figure 4 includes a transmitter 401 that transmits a digital communication signal 402 through the upstream channel 403. The

transmitter 401 comprises an encoder 404, a transmission filter 405, and a modulator 406. The transmission filter 405 comprises a cascade of a spectral shaping filter 407, a square-root raised cosine filter 408, a fixed shaping filter 409, and a trained pre-equalizer 410. It is recognized that the above transmitter structure may be supported by the current MCNS specification, and therefore may be supported by current MCNS implementations.

The encoder 404 may include any Forward Error Correction (FEC) code such as Reed-Solomon encoding. It is recognized that the encoder may include an interleaver within the packet, in order to combat impulse/burst noise, but this approach requires a modification to the DOCSIS specifications. One may also use other signal constellations than those specified in [1] such as pi/4-QPSK, offset-QPSK, 8PSK, 32QAM, 64QAM, 128QAM, 256QAM, depending on channel conditions. Another possibility is to use Tomlinson precoding for avoiding a DFE at the receiver 411, but that again will deviate from the MCNS specification.

The spectral shaping filter 407 may take the form of a "duo-binary filter" $(1+z^{-1})$ or any other pre-equalizer that can be used to achieve an approximation to the water-pouring spectral density in conjunction with a DFE receiver, e.g. $(1+e^{-j\omega_0}z^{-1})$ for elimination of narrow-band interference at ω_0. The purpose of the shaping filters 407 408 409 is to reduce adjacent channel interference (ACI). The fixed shaping filter 409 is designed for a "more or less" known level of Signal-to-Noise (SNR) ratio and Signal-to-Interference (C/I) ratio, and may be loaded during ranging when the C/I and SNR are assessed. The trained pre-equalizer 410 is essentially the inverse 1/H of the transfer function of the upstream channel 403, and it is trained at the receiver 411, where the parameters describing the channel H are transmitted to the CM through the downstream channel 105.

The transmitted signal 402 is impaired by the linear distortion H of the upstream channel 403, by non-linear distortions, and by additive noise sources, including Ingress noise 412, and ACI 413.

The receiver 411 consists of a modified matched filter (MMF) 414 which is a convolution of square-root raised cosine filter 415 and a pre-calculated filter 416 working at N times the symbol rate (e.g. N=2). This filter may be loaded from a table according to the estimated C/I and SNR. We note that the filter 416 may be jointly designed with the transmission filter 405 in some optimal manner to improve the overall SNR and C/I at the receiver 411.

The output of the MMF 414 is fed to an adaptive equalizer 417, followed by a decoder 418, which may include additional filtering, Viterbi detector, and FEC decoder.

An example of an adaptive equalizer is depicted in Figure 5. It is an adaptive Decision Feedback Equalizer (DFE), operating in a noise prediction configuration 501, and it may be preceded by an adaptive FSE 502. By using the adaptive FSE it is possible to reduce the magnitude of the DFE taps, with tap leakage procedures, and thus reduce DFE error propagation. To avoid any error propagation at all, one can use only the adaptive FSE, and completely avoid the DFE. The equalizer taps are modified by a Linear Mean Square (LMS) approach. It can be trained during the ranging phase of the CMTS, and/or pre-loaded using prior knowledge of channel spacing, and perhaps C/I and SNR.

Figure 6 depicts the structure of the decoder when a duo-binary pulse $1+z^{-1}$ is used. The equalizer 601 is adjusted to achieve a sum of two symbols at its output. The output of the equalizer passes through a $1+z^{-1}$ filter 602, and then goes to the Viterbi detector 603. For example, if the encoder output 419 in Figure 4 is QPSK symbols $\pm 1 \pm j$ then the modified slicer 604 of the DFE searches for constellation points $I+jQ$, where I and Q can have values of 2, 0, and -2. The adaptive DFE 605 is trained to minimize the error between the slicer input and the slicer output.

The complexity of the Viterbi is 4 states and 16 branches per QPSK symbol and 16 states and 256 branches in 16QAM. A reduced 16QAM version of 4 states and 16 branches per symbol can be considered.

We note that instead of a DFE one may use advance equalization techniques such as maximum likelihood sequence estimator (MLSE). The idea here is to implement noise prediction and compensation of deliberate ISI due to transmission pulse using Reduced Viterbi equalizer.

The FEC decoder 606 may be implemented using a conventional Reed-Solomon decoder (if this is the code being used in the system). Alternatively one can used the configuration depicted in Figure 7, where the burst noise identifier 701 identifies exceptional data point, based on inputs from the Analog Front End (AFE) 702 and the QPSK/16QAM receiver 703, and analyzes the presence and the length of noise burst. , The Reed-Solomon decoder 704 uses erasures for the data bytes that suspected to be infected by noise.

The exceptional data points are detected by either

- Saturations or very large values of the data at the signal path (e.g. at the slicer input)
- A sequence of large error values at the slicer
- In re-transmission mode: When the two signals yields different symbol decisions.

The receiver has a state machine which estimate burst duration according to the indication of exceptional data points and put the Reed-Solomon decoder on an "erasure" mode during the burst.

In addition to the above, the receiver performs clipping of signals with exceptionally large magnitude.

It is recognized that the present invention can be used in conjunction with reduced spaced signal constellation, such as depicted in Figure 3, by following the procedures in [2]. In paricular, the algorithm may iterate as follows:

For a set of overlapping signals,

Subtract previously processed signal from the received signal;

Detect a signal using the receiver 410; and

Re-modulate the signal.

end

The algorithm should start with the signal having the best C/I and SNR (typically the strongest signal, or a signal that have only one overlapping ACI, rather than two).

Pairs of severely interfering signals may be jointly detected using an uncoded joint maximum likelihood approach, as part of the iterations of a method, the general procedure of which is outlined in [2]. The joint maximum likelihood procedure involves Viterbi-like algorithm for which a trellis diagram with a branch metric is defined. The complexity of such approach, based on a memory constraint of 3 symbols for each signal is 16 states and 256 branches per symbol with QSPK, and 256 states and 64K branches per symbol in 16QAM. The number of transitions can be significantly reduced using reduced state Viterbi algorithm, e.g. by discarding states in the trellis diagram that are unlikely for the current signal sample. The algorithm then selects a survivor path for each of the remaining new states based on the cumulative metric for all possible paths entering the new state from the previous states, followed by the selection of the leading path, and detection of the information bits. The algorithms then discards unlikely new states based on the cumulative metrics.

It is also recognized that the present invention can be used in conjunction with a frequency hopping scheme, using a joint frequency/time axis forward error correction and interleaving.

As part of signal acquisition stage, in which the received signal parameters are estimated the receiver 411 makes use of a preamble field in a data packet. In the presence of impulse and burst noise the preamble should be longer than the duration of the longest error burst that can be recovered by the receiver (i.e. at least $2t$ bytes if Reed-Solomon block code $(N-t,N)$ is used, where N is the block size.

The preamble is split to sections and the receiver identifies sections that are noisy (e.g. according to the residual error between the incoming signal and the expected signal according to the known training data and estimated parameters). Sections that are noisy (due to impulse/burst noise) are neglected.

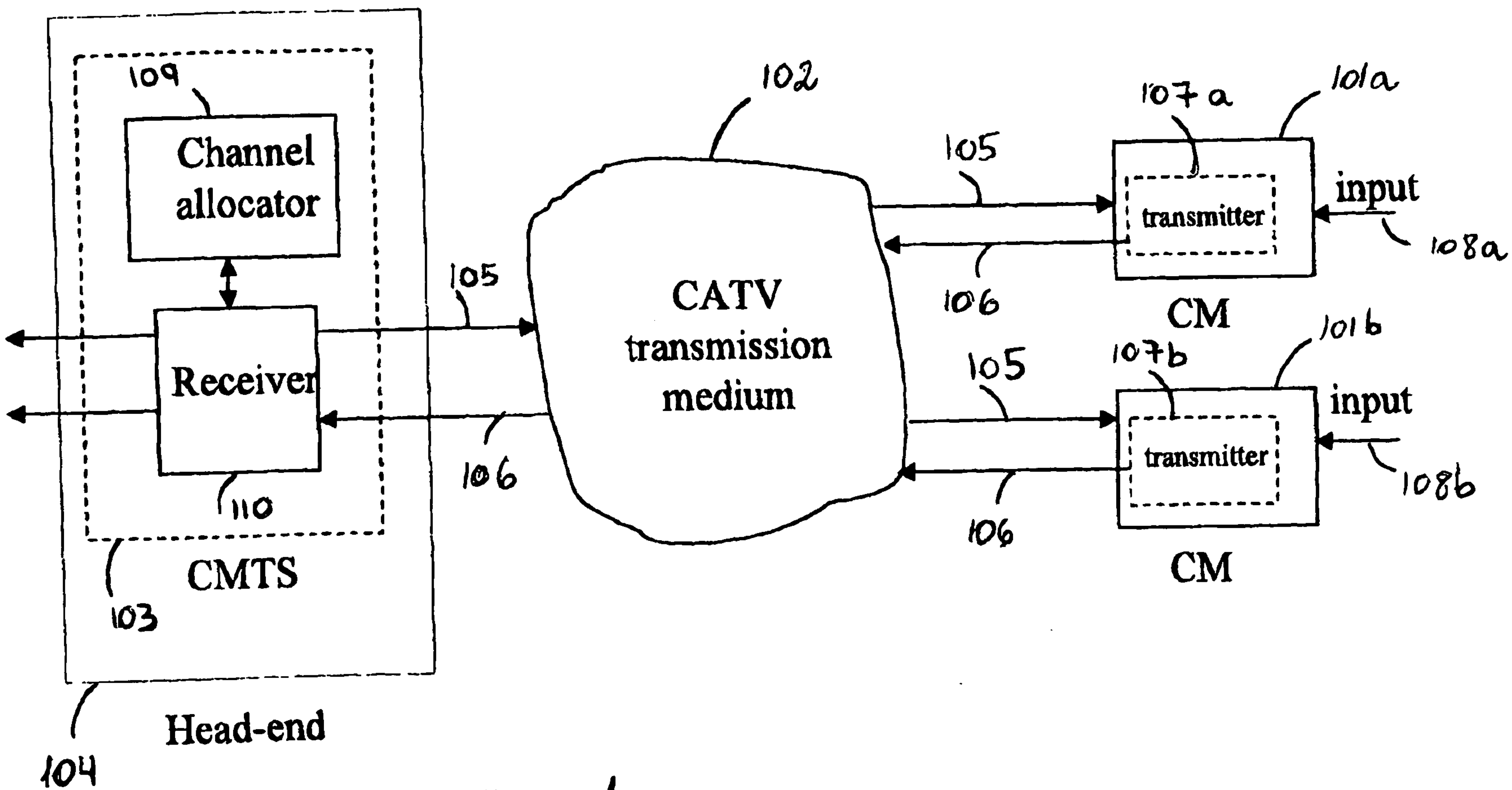
In case the receiver is capable of recovering a very long error burst, particularly, if interleaving is used, then one may consider the following structure of a packet: PDDDPDDDD…D, where P is a preamble section and D is a data section. The distance between P sections will be larger then the maximum burst length that can be received.

The acquisition performance can be severely effected by narrow-band interference, such as ingress noise (narrow band interference) or partially overlapping channels. We propose using a preamble that is designed to have low spectral density at the noise frequency regions, and high spectral density at the regions of low noise. This can be achieved using pre-equalizer in the transmitter, or by using a non-white sequence of symbols. As a byproduct, the interference of the transmitted preamble into overlapping adjacent channels will be reduced, enabling a robust acquisition for scenario of overlapping signals.

References

[1] Data-Over-Cable Interface Specifications: Radio Frequency Interface Specification SP-RF1101-970321, MCNS Holdings, L.P., March 21, 1997

[2] Mordechai Segal, Ofir Shalvi (Inventors), Libit Signal Processing Ltd. (Assignee), Method and Apparatus for Digital Communication in the Presence of Closely Spaced Adjacent Channels. US Patent 5,710,797 Jan. 20, 1998.



109
Channel allocator
Receiver
110
CMTS
103
Head-end
104
105
106
102
CATV transmission medium
105
106
105
106
107a
101a
transmitter
input
108a
CM
107b
101b
transmitter
input
108b
CM

Figure 1

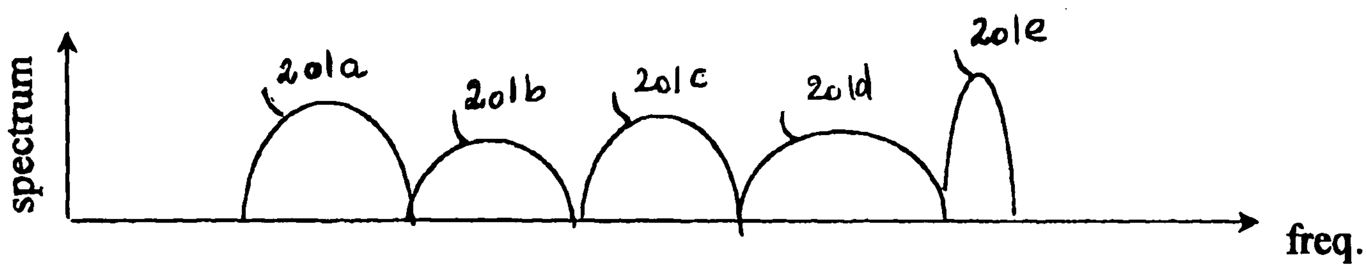


Figure 2

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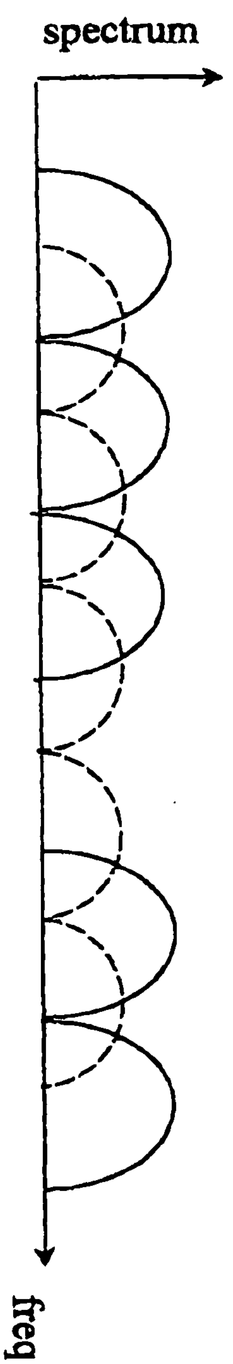

Figure 3

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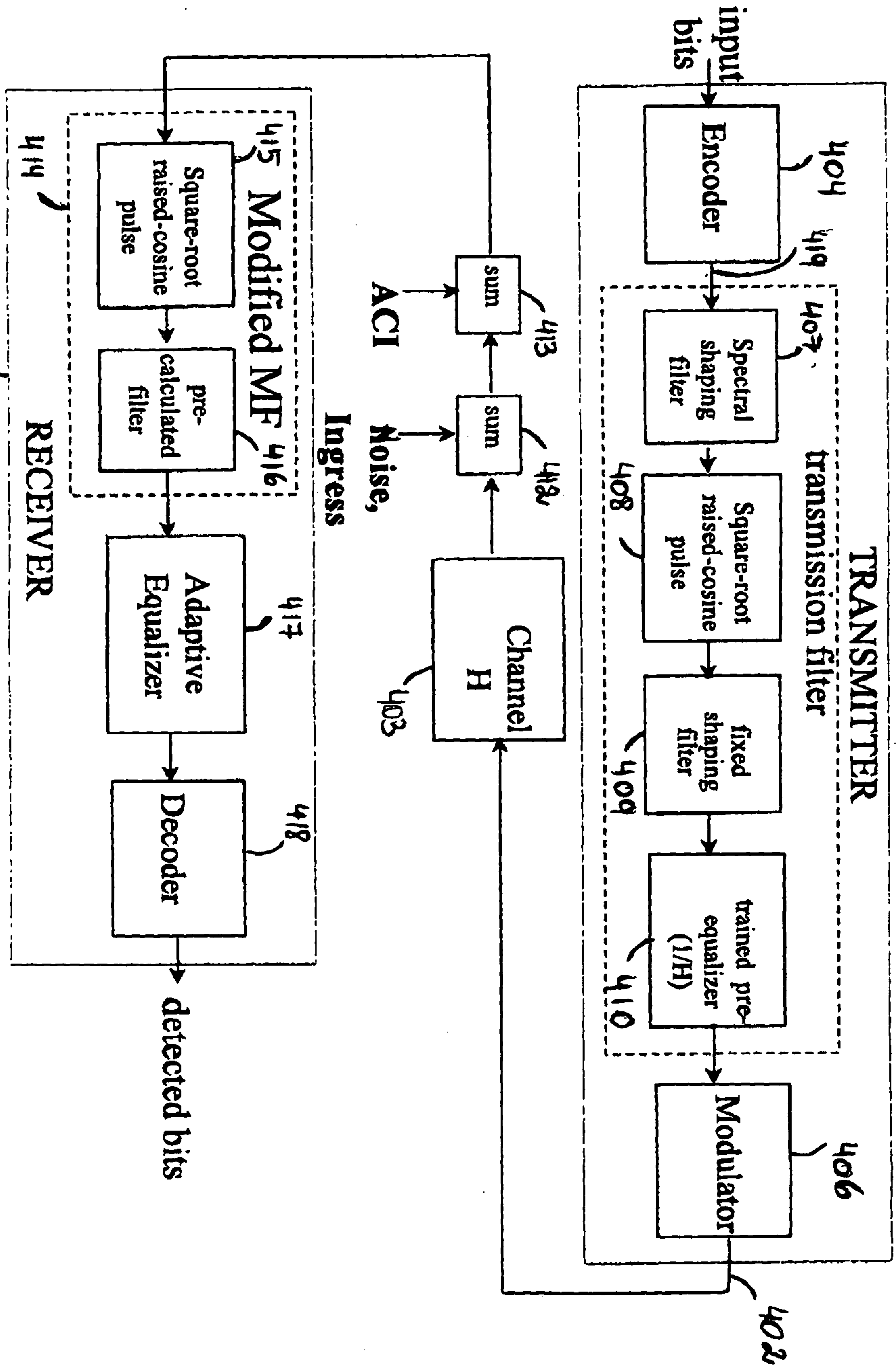

Figure 4

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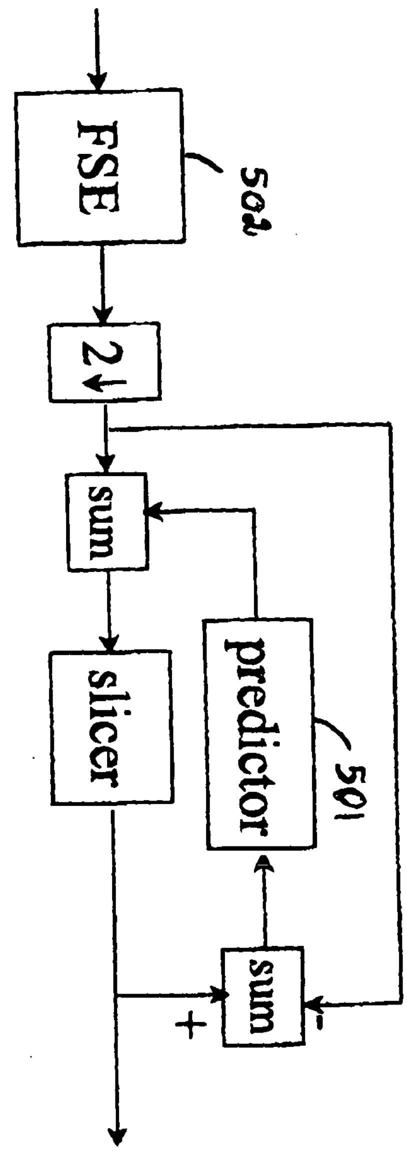

Figure 5

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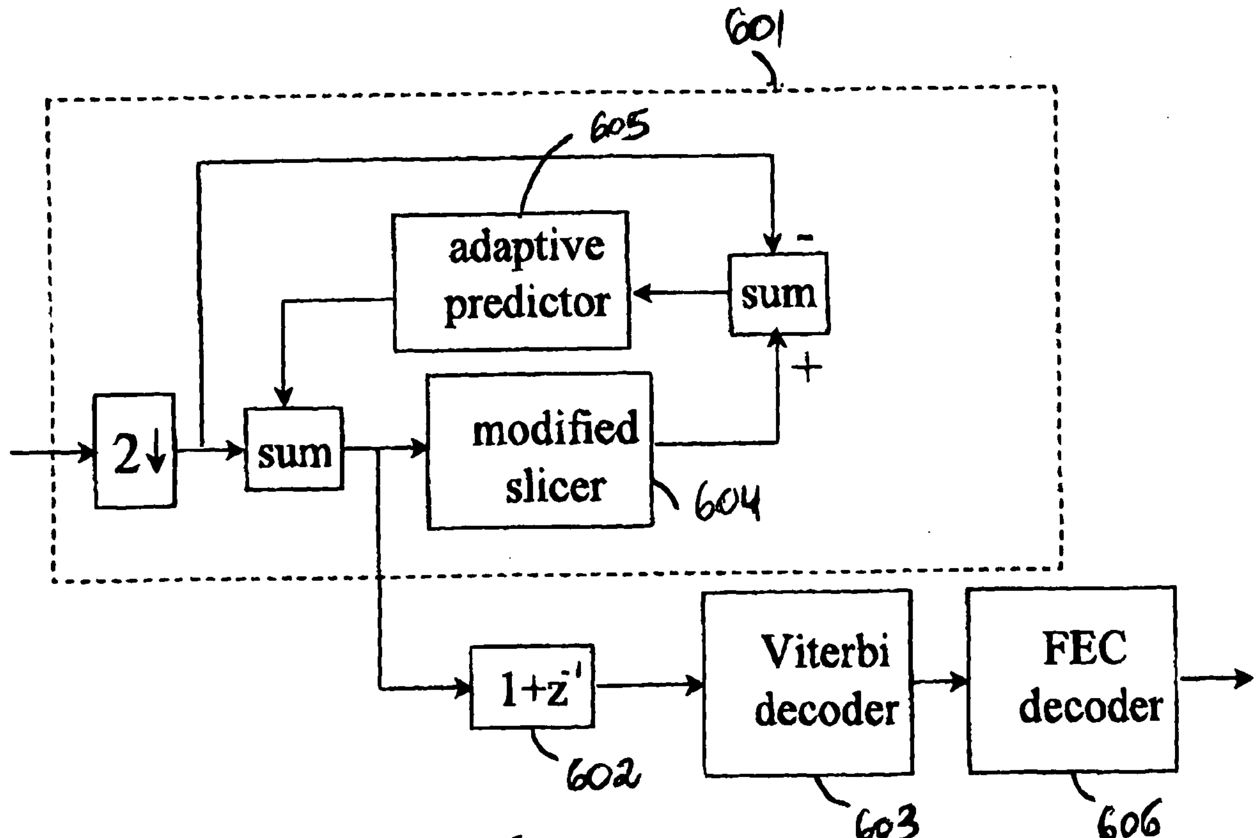

Figure 6

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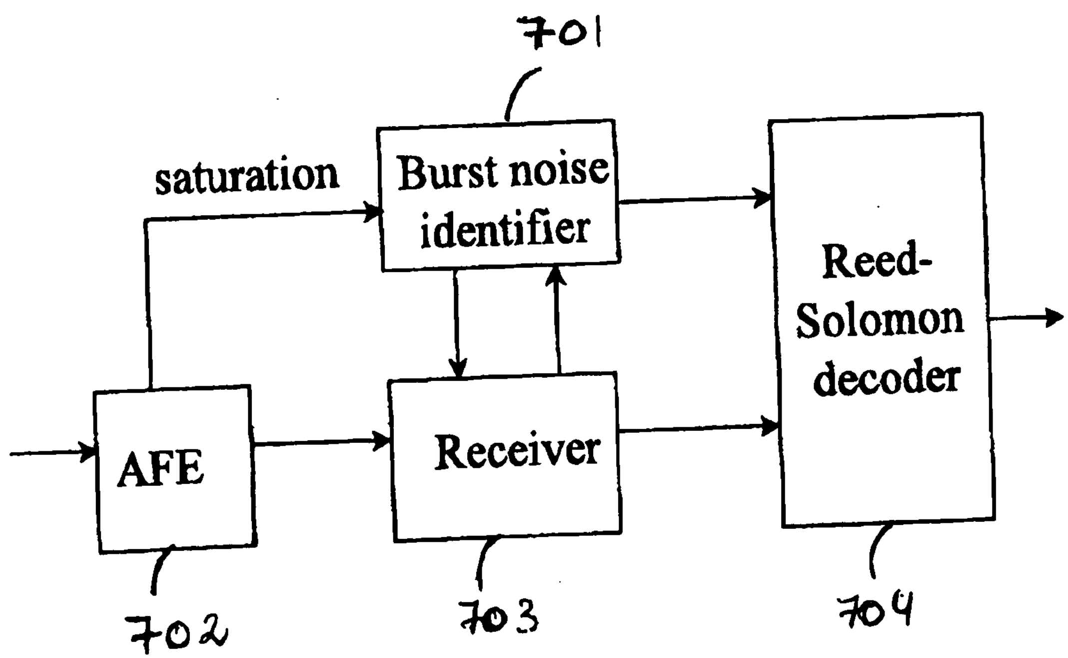

Figure 7

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